Swift Creek Reservoir
Water Quality Data Report 2013

*Photo courtesy of Jim Waggoner

Chesterfield County
Department of Environmental Engineering
Water Quality Section
&
Department of Utilities
Addison-Evans Water Production/Laboratory Facility

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Executive Summary

This report presents the water quality data collected by the Addison-Evans Water Production and Laboratory Staff for the period of January through December 2013 and represents the twenty first consecutive year of monitoring of the Swift Creek Reservoir. During 2013, pool elevations measured at the dam ranged from 174.6 to 177.7 feet above mean sea level, corresponding to approximate reservoir volumes of <3.5 to 4.9 billion gallons. Reservoir sampling occurred once a month at eight stations with additional samples obtained every other week at the lacustrine zone. Rainfall over the reservoir and its watershed totaled 47.51 inches, 5.08 inches above the long-term average. During 2013, approximately 200 pounds of copper sulfate were applied in July to treat algae growth in the reservoir. The applications of copper sulfate assist to improve source water quality for the optimization of the water treatment process.

An overall higher concentration of chlorophyll *a* was observed in 2013, as compared to 2012, indicating an increased presence of algae in the reservoir. The growing season 90^{th} percentile concentration for the mainstem reservoir stations (Stations 4, 5, 6 and 8) was 22.5 µg/L; slightly greater than the 20.2 µg/L value observed in 2012. No individual chlorophyll *a* concentration measurement or growing season 90^{th} percentile value exceeded the state water quality criterion of 35 µg/L, indicating acceptable levels of algal growth in the reservoir.

Throughout the reservoir, a slight increase in total phosphorus concentration was observed. The growing season median total phosphorus concentration for the surface water of the main body stations (Stations 4, 5, 6 and 8) was 0.036 mg/L as P; below the Virginia Department of Environmental Quality (VADEQ) nutrient threshold of 0.04 mg/L as P. The annual median phosphorus concentration for the surface water at all eight sites in Swift Creek Reservoir was 0.036 mg/L as P, below the county goal of 0.05 mg/L as P.

During 2013, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper areas beginning in early April and lasting through mid-September. During the stratification period, dissolved oxygen concentrations within the epilimnion were well above the VADEQ criterion of 4.0 mg/L for all stations.

Median growing season Secchi disk readings ranged from 1.5 to 3.5 feet, similar to values noted in prior reports. The growing season median throughout the reservoir for turbidity (4.5 NTUs) during 2013 remained consistent with the previous year indicating the overall water clarity is good and unchanged. The long-term consistency of both the Secchi disk depth and turbidity parameter measurements suggests minimal long term variability in water clarity. The growing

season median total suspended solids concentration for all stations (8.6 mg/L) was greater than the 2012 observation (4.4 mg/L) and was among the highest median growing season concentrations noted to date. As in the previous years, total nitrogen levels remained consistent throughout the reservoir. The growing season total nitrogen concentrations were less than observed in past years with site medians ranging from 0.57 to 0.67 mg/L as N and indicated a decrease in nitrogen enrichment. *E. coli* densities remained acceptable with no values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL during the growing season.

Water temperature in Swift Creek Reservoir varied normally according to season during 2013. Surface pH values ranged from 6.2 to 8.0 units with an annual in-lake median of 7.0 units. Conductivity measurements within the reservoir ranged from 20 to 250 µS/cm with an annual median of 74 µS/cm. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0210 mg/L with twenty measurable concentrations noted during 2013. Zinc levels were typically below the laboratory's detection limit (0.05 mg/L) with only one measurable concentration.

A total of 46 individual genera of algae representing six phyla were documented during 2013. Analysis of the general types of algae by phyla in the reservoir indicated that the community structure continued to be comprised largely of green algae (Chlorophyta) and golden algae/diatoms (Chrysophyta). While common, the frequency of occurrence for the taste and odor producing blue-green algae has remained low and was similar to levels observed in 2012. There were no widespread taste and odor related problems resulting from algae reported in 2013.

The reduction in the density and distribution of *Hydrilla* within the Swift Creek Reservoir following the introduction of the grass carp has been rapid and successful. Since the August 2011 survey, no extant areas of *Hydrilla* have been observed in the reservoir. While the vegetative structures of the plant have been virtually eliminated, it is anticipated that the plant's presence has not been completely removed. Constant and consistent evaluation of the situation is continuing and the eventual replacement of the existing, aging grass carp population is anticipated.

Introduction

This report presents the water quality data collected by the Addison-Evans Water Production and Laboratory staff between January and December 2013 and is the twenty first consecutive year of monitoring of the Swift Creek Reservoir. The Swift Creek Reservoir is a public water supply for Chesterfield County located approximately 20 miles southwest of Richmond, Virginia. The reservoir is a 1700-acre impoundment containing approximately 5 billion gallons of water at full pool elevation (177.0 feet above mean sea level). The portion of the Swift Creek Reservoir watershed located within the northwest corner of the county encompasses 51.3 square miles. Although residential development is common in the reservoir's drainage area (31.7% for all residential categories), the most recent land use data (Table 1) indicates the majority (57.0%) of the watershed is comprised of vacant properties.

Table 1. Land Use Characteristics of the Swift Creek Reservoir Watershed within Chesterfield County. Data obtained from the Chesterfield County Planning Department Development Potential Database 2013 (DPD 13). Categories are arranged in descending order of prevalence.

Land Use Type	Area (acres)	Area (miles^2)	Percent of Watershed
Vacant	18,735	29.3	57.0
Residential - Single Family (Subdivisions)	10,041	15.7	30.6
Water	1,607	2.5	4.9
Public/Semi-Public	1,394	2.2	4.2
Commercial	340	0.5	1.0
Residential – Multi-family	212	0.3	0.6
Utility	216	0.3	0.7
Office	102	0.2	0.3
Residential – Condominium	77	0.1	0.2
Residential – Townhouse	86	0.1	0.3
Industrial	38	0.1	0.1
Total	32,848	51.3	100.0

During 2013, pool elevations measured at the dam ranged from 174.6 to 177.7 feet above mean sea level, corresponding to approximate reservoir volumes of <3.5 to 4.9 billion gallons. Reservoir sampling occurred once a month at eight stations with additional samples obtained every other week at the lacustrine zone Stations 5 and 8 (Figure 1). At these deeper water sites, discrete epilimnion, metalimnion, and hypolimnion samples were taken for nutrient analysis. All other stations in the reservoir (sites 1, 2, 3, 4, 6 and 7) were sampled at the surface only.

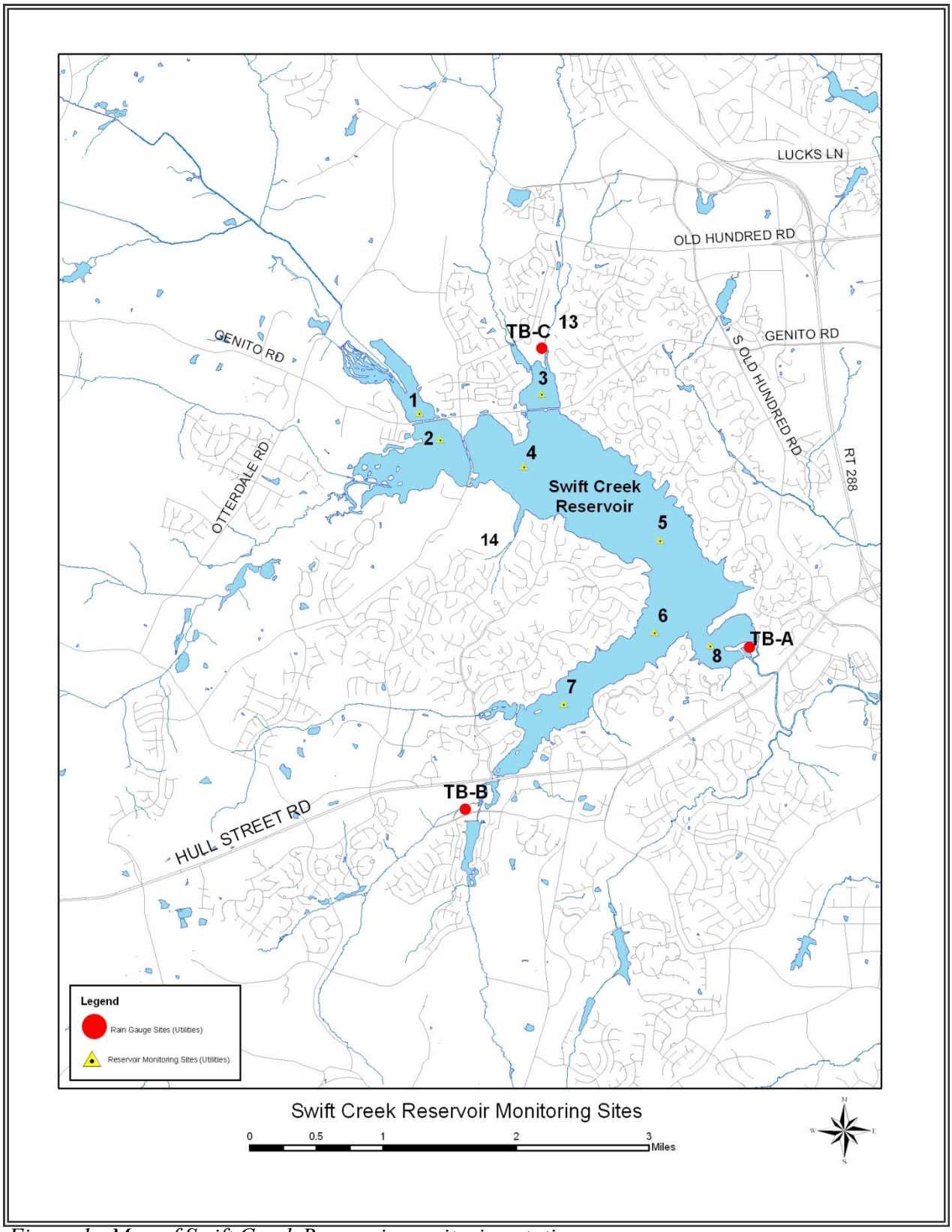


Figure 1. Map of Swift Creek Reservoir monitoring stations.

Water quality parameters (Table 2) were chosen to provide information on basic water quality and the ecological health of the reservoir. Details concerning specific analytical procedures are listed in Table 3.

Table 2. Sampling Regime for Swift Creek Reservoir 2013.

PARAMETERS	RESERVOIR STATIONS 1,2,3,4,5,6,7,8	RESERVOIR STATIONS 5,8
DEPTH	X1	X1
SECCHI DISC	X	X
WATER TEMPERATURE	X1	X1
DISSOLVED OXYGEN (Given as mg/L & % saturation)	X1	X1
CONDUCTIVITY	X1	X1
pH	X1	X1
OXIDATION REDUCTION POTENTIAL	X1	X1
TOTAL PHOSPHORUS	X2	X3
ORTHO PHOSPHATE PHOSPHORUS	X2	X3
TOTAL KJELDAHL NITROGEN	X2	X3
OXIDIZED NITROGEN	X2	X3
AMMONIA NITROGEN	X2	X4
TOTAL ORGANIC CARBON	X2, 1/QTR	X2, 1/QTR
LEAD	X2, 1/QTR	X2, 1/QTR
ZINC	X2, 1/QTR	X2, 1/QTR
SUSPENDED SOLIDS/TURBIDITY	X2	X2
CHLOROPHYLL *a*	X5	X5
PHEOPHYTIN *a*	X5	X5
ALGAE COUNTS	X5	X5
FECAL COLIFORMS (*E. coli*)	X2	X2

X1 – ONE METER INTERVALS
X2 – SURFACE SAMPLING ONLY
X3 – DISCRETE SAMPLES OF EPILIMNION, METALIMNION AND HYPOLIMNION WHEN STRATIFICATION EXISTS **OR** SURFACE, MID-DEPTH AND NEAR BOTTOM WHEN NO STRATIFICATION IS PRESENT
X4 – DISCRETE SURFACE AND NEAR BOTTOM SAMPLES
X5 – A COMPOSITE OF BENEATH SURFACE, 1/2/ SECCHI DEPTH, SECCHI DEPTH AND 1-1/2 SECCHI DEPTH SAMPLES

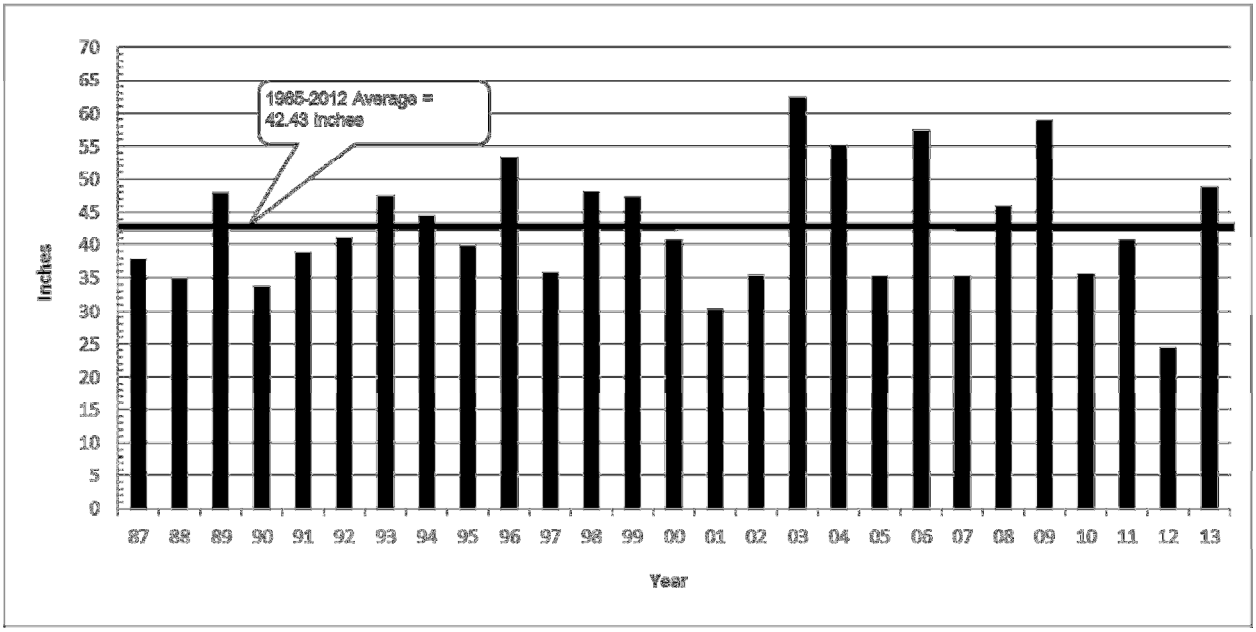
Table 3. Parameters and Analytical Methods 2013. When Reporting Limit based upon detection is not an applicable measurement for a parameter, it has been replaced by an estimation of accuracy (e.g. pH measurement has an estimated accuracy of 0.2 units) as indicated by (*).

Parameter	Analytical Method	Detection Limit[1]
Depth	Probe: Hydrolab MiniSonde	± 0.08 m*
Dissolved Oxygen	Probe: Hydrolab MiniSonde	± 0.2 mg/L*
Oxidation Reduction Potential	Probe: Hydrolab MiniSonde	± 20mV*
Water Temperature	Probe: Hydrolab MiniSonde	± 0.1 ^{o}C*
Conductivity	Probe: Hydrolab MiniSonde	± 0.001 µmhos/cm*
pH	Probe: Hydrolab MiniSonde	± 0.2 units
Stage	USGS Staff Gauge	± 0.01 ft*
Flow	Flowmeter: ISCO, Bubble-line	± 0.001m^3/s*
Secchi Depth	20 cm Standard Secchi Disk	± 0.1 ft*
Total Phosphorus	Skalar:EPA Approved, Autom.	0.005 mg/L as P
Orthophosphate	Skalar:EPA Approved, Autom.	0.005 mg/L as P
Total Kjeldahl Nitrogen	Skalar:EPA Approved, Autom.	0.05 mg/L as N
Oxidized Nitrogen	Skalar:EPA Approved, Autom.	0.01 mg/L as N
Ammonia-N	Hach, Salicylate Method 2460	0.03 mg/L as N
Total Organic Carbon	Standard Methods, 5310C	0.5 mg/L
Lead	EPA 200.9, Platform Furnace	2.5 µg/L
Zinc	EPA 289.1, Flame	50 µg/L
Total Suspended Solids	Standard Methods, 2540D	1.0 mg/L
Chlorophyll *a*	Standard Methods, 10200H-3, Fluorom.	1.0 µg/L
Pheophytin *a*	Standard Methods, 10200H-3, Fluorom.	1.0 µg/L
Algae Counts	Standard Methods, 10200F	1 cell/mL
Fecal Coliform (*E.coli*) Density	Standard Methods, 9222B (Quanti-Tray)	1.0 MPN/100mL

NOTE: Standard Methods for the Examination of Water and Wastewater, 19th Edition.

Rainfall was measured at three automated tipping bucket rain gages within the watershed. The average rainfall over the watershed totaled 47.51 inches during 2013 (Figure 2). Rainfall was 5.08 inches above the long-term average observed over the last 28 years (42.43 inches).

Figure 2. Total Annual Estimated Rainfall Recorded for Swift Creek Reservoir Watershed from 1985-2013(Source data: Department of Utilities).



Quality Assurance and Quality Control

All analytical methods used were approved by the United States Environmental Protection Agency (EPA), in accordance with *Standard Methods for the Examination of Water and Wastewater (Standard Methods)* with the exception of the free ammonia analysis, which was conducted following the Hach Chemical Company's test kit procedure. Manufacturers' recommended preventive maintenance procedures were followed for all instruments. For each parameter analyzed, Method Detection Limits (MDLs) were calculated following the EPA procedure as detailed in the *Code of Federal Regulations (CFR), Volume 46, Part 136 Appendix B (EPA, 1984).* Stock and standard solutions were prepared from American Chemical Society reagent grade materials for preparation of calibration standards. Correlation coefficients were evaluated for each calibration curve and had to be greater than or equal to 0.995 to be used for analysis. To ensure calibration validity throughout an analysis, Continuing Calibration Verifications (CCV) standards were tested after every 10 samples analyzed. Similarly, Continuing Calibration Blanks (CCB) were evaluated after every 10 samples to detect any baseline drift errors. With each analysis, field blanks and digestion/analytical blanks were

evaluated to ensure detection of contamination during sampling or sample preparation. Independent source Standard Reference Materials (SRM) were purchased and used to verify the accuracy of each analysis calibration. When any SRM was not within ten percent (per EPA guidelines) of the true value, or CCB showed baseline drift, corrective actions were implemented and samples reanalyzed. An annual Environmental Resource Associates (ERA) performance evaluation of blind nutrient samples in a split sampling study was conducted and reported concentrations for orthophosphate and total phosphorus, ammonia, oxidized nitrogen, and total Kjeldahl nitrogen were within the limits of the ERA's acceptable analytical values.

Results and Discussion

Eight stations in the reservoir were sampled monthly during 2013. Stations 5 and 8 were sampled twice per month throughout the year to obtain additional data for the deep-water areas. Sampling at all stations included surface grab samples and water column profiles of physical parameters. Supplemental bottom water quality samples were obtained at the mainbody Stations 5 and 8. Specific reports concerning reservoir data are available upon request from the Departments of Environmental Engineering or Utilities.

The county's water quality goal for the annual median concentration of total phosphorus in surface waters is 0.05 mg/L as P or less and was originally based on a Nutrient Controls Standards Workshop held in 1987 by the Virginia Department of Environmental Quality (VADEQ). In June 2006, Virginia Department of Environmental Quality (VADEQ) adopted freshwater nutrient standards for 116 lakes and reservoirs in Virginia, including the Swift Creek Reservoir. The regulations were approved by the EPA in July 2007, and the amended water quality standards [9 VAC 25 - 260] became effective August 14, 2007. These regulations set growing season (April through October) chlorophyll *a* and total phosphorus criteria for Swift Creek Reservoir at 35 µg/L (0.035 mg/L) and 40 µg/L (0.040 mg/L as P) respectively. These growing season measurements are by definition intended not to be exceeded for two consecutive years as measured by the State in their Lake Monitoring Program. Specifically, VADEQ considers the reservoir nutrient enriched if the 90^{th} percentile of the chlorophyll *a* data in surface waters of the main body of the reservoir (Stations 4, 5, 6, and 8) during the growing season exceeds the criteria for two consecutive years. However, algaecides use can make the chlorophyll *a* measurements unreliable. If algaecide are used, then both chlorophyll *a* and total phosphorus criteria are applicable. In the Swift Creek Reservoir, the algaecide copper sulfate is used occasionally to spot treat algal blooms. The algaecide use is variable over the reservoir between months and between years. Because of the algaecide treatments, analysis of the reservoir data has always included both the total phosphorus and chlorophyll *a* criteria. Additionally, VADEQ would consider the reservoir nutrient enriched if the growing season

median concentration of total phosphorus in surface waters of the main body of the reservoir exceeded the criterion for two consecutive years.

During 2013, approximately 200 pounds of copper sulfate were applied in July to treat algae growth in the reservoir. The 200 pounds were applied on July 31, 2013 in the bay adjacent to the water intake tower (in the vicinity of Station 8). All applications of copper sulfate were performed to improve source water quality for the optimization of the water treatment process within the plant. Algal blooms are known causes of taste and odor issues in drinking water and can clog filters decreasing available potable water production and supply.

Chlorophyll *a*

VADEQ has identified chlorophyll *a* as the most important parameter that can be measured to determine the nutrient enrichment status of a reservoir. Chlorophyll *a*, a green photosynthetic pigment found in algae, is an indirect measure of biological response to nutrient loadings. VADEQ considers the threshold value for nutrient enrichment in Swift Creek Reservoir to be the 90^{th} percentile concentration that exceeds 35 µg/L, measured between April and October (*i.e.* the growing season) within the main body for two consecutive years.

An overall higher concentration of chlorophyll *a* was observed in 2013 as compared to previous years indicating an increased presence of algae in the reservoir. This increased presence was confirmed by the increase in algal cell density counts. The growing season 90^{th} percentile concentration for the mainstem reservoir stations (Stations 4, 5, 6 and 8) was 22.5 µg/L (Table 4), slightly greater than the 20.2 µg/L value observed in 2012. This 90^{th} percentile concentration was the largest observed in the mainstem stations combined since 2009. In 2013, all eight of the stations combined had a 90^{th} percentile concentration during the growing season of 23.4 µg/L, an increase from the 19.9 µg/L observed in 2013 but less than the 24.7 µg/L value noted in 2010. The greatest individual measurement observed occurred at two locations in the reservoir: on the western branch of the reservoir (Station 7) and within the intake bay (Station 8) both on October 8, 2013 with the same concentration of chlorophyll *a* (26.9 µg/L). The highest growing season 90^{th} percentile concentration (24.3 µg/L) was observed at Station 7. There continues to be no individual measurements or growing season 90^{th} percentile values exceeding the 35µg/L criteria, indicating acceptable levels of algal growth in the reservoir.

Table 4. Growing Season Chlorophyll a *Concentrations (Surface) 2013.*

Station	Growing Season 90th Percentile Chlorophyll *a* (µg/L)
1	22.1
2	23.8
3	15.9
4	17.4
5	23.9
6	22.2
7	24.3
8	21.3
Mainbody Stations (4, 5, 6, 8)	**22.5**
Shallow Stations (1, 2, 3, 7)	**23.7**
All Stations	**23.4**

Total Phosphorus

Total phosphorus is measured as an indicator of nutrient enrichment. The county has an established goal of not exceeding an annual median in-lake phosphorus concentration of 0.05 mg/L as P in order to maintain water quality. The VADEQ has adopted a freshwater nutrient criterion of 40 µg/L (0.040 mg/L as P) for the surface waters of the reservoir's main body for the growing season. The growing season (April – October) median total phosphorus concentrations for each reservoir station are provided in Table 5.

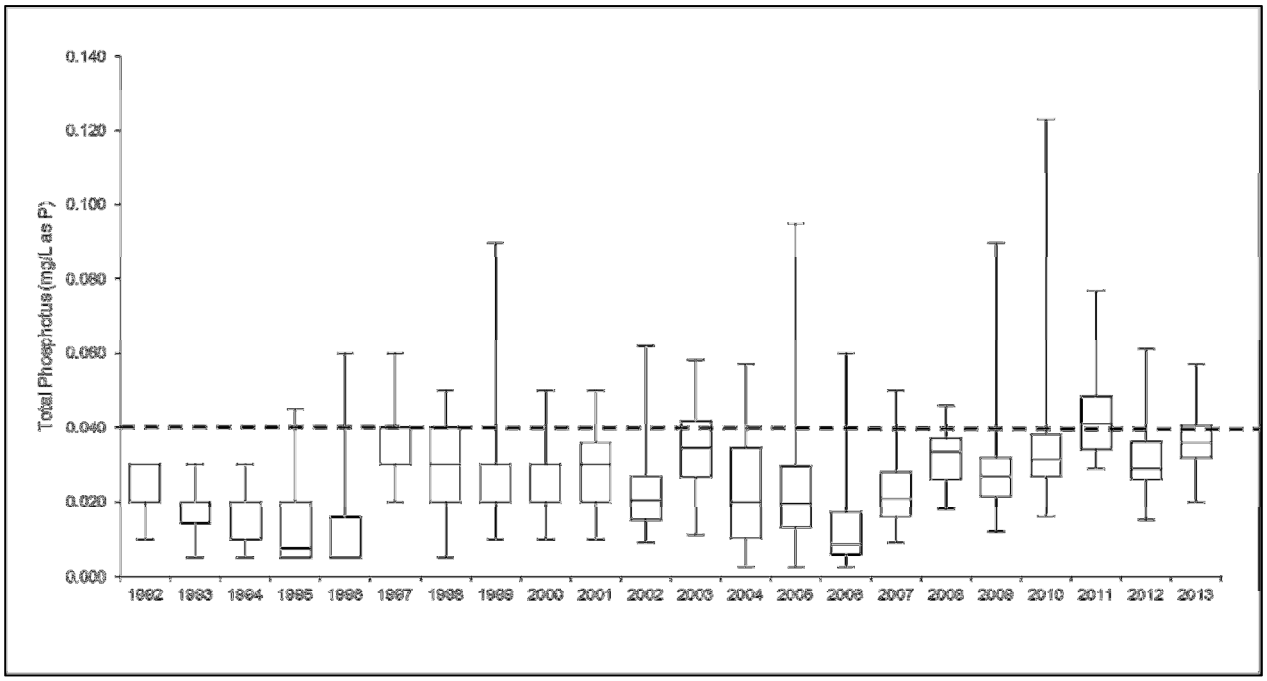
Table 5. Growing Season Median Total Phosphorus Concentrations (Surface) for 2013.

Station	Growing Season Median Total Phosphorus (mg/L as P)
1	0.058
2	0.050
3	0.038
4	0.034
5	0.035
6	0.036
7	0.035
8	0.036
Mainbody Stations (4, 5, 6, 8)	**0.036**
Shallow Stations (1, 2, 3, 7)	**0.040**
All Stations	**0.037**

In 2013, the growing season median total phosphorus concentration in the reservoir for all sites

combined was 0.037 mg/L as P, an observation below the county goal of 0.05 mg/L as P. This observation was a slight increase in total phosphorus concentration as compared to 2012 (0.033 mg/L as P). The growing season median total phosphorus concentration for the surface waters of the main body stations (Stations 4, 5, 6 and 8) was 0.036 mg/L as P, also an increase from the 0.029 mg/L as P concentration noted in 2012. The 2013 growing season median value observed in the mainbody represented a value below the VADEQ freshwater nutrient criterion of 0.04 mg/L as P (Figure 3). With the exception of Stations 1 and 2, all individual station growing season medians were below the 0.04 mg/L as P threshold. At Stations 1 and 2 the growing season medians were greater than 0.04 mg/L as P indicating nutrient enrichment (Table 5). It should be noted that the state phosphorus criterion is only applicable for the lacustrine zone (Stations 4, 5, 6 and 8) and is not intended as a regulatory value for the shallow, backwater areas of the reservoir. During the 2013 growing season, for all sites monitored in the reservoir, 39 individual measurements (32.5%) were at or exceeded 0.04 mg/L as P, this was a slight increase from the 2012 observations (n=28; 25.0%). The annual median phosphorus concentration for all eight sites was 0.036 mg/L as P. The total phosphorus levels present in Swift Creek Reservoir indicate that in 2013 this water body exhibited a slight increase in nutrient enrichment.

Figure 3. Box plot demonstrating the growing season median total phosphorus concentrations and ranges of observations for the surface waters of main body sites within Swift Creek Reservoir 1992 - 2013. Dashed line denotes VADEQ maximum threshold of 0.04 mg/L as P for acceptable water quality.



Higher concentrations of total phosphorus in anoxic (oxygen depleted) bottom waters as compared with surface water concentrations indicate active phosphorus release from sediments. The release of phosphorus from the sediments results in additional nutrient loading to the reservoir, as this phosphorus is then mixed with the upper water layers during de-stratification. At Stations 5 and 8 during 2013, there were 25 instances where the concentrations of total phosphorus in the benthic sample were greater than the values obtained at the surface; a decrease from the 33 observed in 2012. Of these 25 instances, five were considered substantial (*i.e.* ≥50% difference) with two occurring during a period of true anoxia (dissolved oxygen concentration ≤ 1.0 mg/L) near the benthic sediment. This is a decrease from 2012 in both the number of substantial differences (nine) observed and the number of true anoxic events (eight). These observations were made during the period from June to September at Stations 5 and 8 with bottom phosphorus concentrations ranging from 0.022 to 0.097 mg/L as P. This represented a median bottom concentration of 0.037 mg/L as P and a differential of 6% increase as compared to the median surface concentration (0.035 mg/L as P). The remaining differences noted were either minor (≤50% difference) or were observed when true anoxia in the benthos was not present. While total phosphorus contributions from the sediment were not significant, the higher concentrations in the anoxic hypolimnion continue to contribute to loading with the reservoir. Incrementally, the sediments are increasing the loading to the overall water column phosphorus budget.

Dissolved Oxygen

Adequately oxygenated water is critical for a healthy aquatic environment and as good quality source water for municipal treatment facilities. Hypoxic conditions occur when dissolved oxygen drops below 5.0 mg/L, resulting in stress on fish and other aquatic life. An anoxic condition occurs when dissolved oxygen drops below 1.0 mg/L, which can result in fish kills and the release of phosphorus, iron, manganese and other elements from the sediments. The release of these elements can result in increased algal blooms and treatment problems (undesirable tastes and odors) for the production of drinking water.

In July 2007, EPA approved the VADEQ's proposed dissolved oxygen standard (5.0 mg/L daily average, 4.0 mg/L minimum), which had been modified to account for naturally occurring decreases in dissolved oxygen due to thermal stratification in reservoirs. These new standards apply to the entire water column when the reservoir is well mixed and only to the surface waters (epilimnion) when the water column is vertically stratified. From 2002 to 2006, Swift Creek Reservoir was listed on the VADEQ's 303(d) listing of impaired water bodies for not meeting the dissolved oxygen standard due to naturally occurring conditions. The most recent 2012 VADEQ's 303(d) listing of impaired water bodies does not include the Swift Creek Reservoir.

Thermal stratification is a natural process in many lakes and reservoirs that occurs when summer conditions warm the upper water column while the lower water column remains cooler. The warmer surface waters become lighter than the colder and denser bottom waters, resulting in layers of water separated by a zone of sharply changing temperature, known as a thermocline, which inhibits vertical mixing. The thermal stratification continues until falling temperatures in the autumn cool the surface water sufficiently disrupt the thermocline. Often a large fall storm event will result in rapid de-stratification of the lake.

During 2012, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper sections beginning in early April and lasting through mid-September. Thermal stratification of Swift Creek Reservoir was first observed on April 9, 2013 at Station 8, corresponding with the first substantial drop in dissolved oxygen levels at and near the bottom. Stratification continued at both Station 5 and 8 until September 23, 2012, when the lake turned over and became thoroughly mixed. Destratification most likely corresponded with a storm event that occurred on September 21, 2013 when 0.71 inches of rain was recorded at the water plant. During the stratification period, dissolved oxygen concentrations within the epilimnion were above the VADEQ standard of 4.0 mg/L minimum for all stations. The time period and degree of thermal and dissolved oxygen stratification within Swift Creek Reservoir were consistent with past observations.

Secchi Depth, Total Suspended Solids, Turbidity, Total Nitrogen and Fecal Coliforms

Secchi depth is a measurement of water transparency using a weighted black and white disk that is lowered into the water until the distinction between the black and white portion are no longer visible. The depth at which the distinction is no longer visible is then recorded as "Secchi disk transparency". Secchi disk transparency is a function of the reflection of light from the surface off the disk. Secchi disk transparency is affected by the light absorption characteristics of the water as well as by dissolved and suspended particulate matter. It provides an estimate of water clarity and is closely related to turbidity.

All stations had median growing season Secchi disk readings ranging from 1.5 to 3.5 feet (Table 6); these results are similar to those observed in prior reports. The 2013 growing season median value for all sites (3.0 feet) was slightly greater than the median observed in 2012 (2.6 feet) but similar to the depth observed in previous years (3.0 feet, 2010 & 2011). Individual site growing season medians for turbidity ranged from 2.4 to 17.0 NTUs with the greatest turbidity observed in the shallow backwater stations. The growing season turbidity median (5.2 NTUs) was similar to that observed in 2012 (4.5 NTUs). The long-term consistency of both the Secchi disk depth and turbidity parameter measurements suggests good water clarity with minimal variability.

Table 6. Growing Season Median Values for Select Parameters (Surface) 2013.

STATION	SECCHI DEPTH (Feet)	TURBIDITY (NTUs)	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL NITROGEN (mg/L as N)	FECAL COLIFORM (*E. coli*) (MPN/100 mL)
1	1.5	10.0	9.5	0.67	12.1
2	1.5	8.4	10.0	0.67	11.0
3	2.3	6.7	6.8	0.66	8.5
4	2.7	4.0	7.6	0.65	6.3
5	3.0	3.8	7.5	0.57	1.5
6	3.3	4.0	7.5	0.53	5.2
7	3.1	4.1	7.8	0.63	4.1
8	3.5	3.5	7.4	0.59	5.7
Mainbody Stations (4, 5, 6, 8)	**3.0**	**3.8**	**7.5**	**0.58**	**4.1**
Shallow Stations (1, 2, 3, 7)	**2.0**	**7.6**	**8.7**	**0.65**	**9.8**
All Stations	**3.0**	**4.5**	**8.6**	**0.62**	**5.2**

The 2013 growing season median total suspended solids concentration for all stations (8.6 mg/L) was nearly double the concentration observed in 2012 (4.4 mg/L) and among the greatest median growing season suspended solids concentrations observed. As in previous years, total nitrogen levels remained fairly consistent throughout the reservoir with growing season median concentrations ranging from 0.57 to 0.67 mg/L as N (Table 6). The 2013 growing season median for all stations (0.62 mg/L as N) was similar to that observed in 2012 (0.66 mg/L as N) and indicated a slight decrease in nitrogen enrichment throughout the reservoir. The mainbody stations' growing season medians were typically less than those noted at the shallow backwater stations.

Fecal coliform densities as expressed as the Most Probable Number (MPN) of *E. coli* per 100mL ranged from a growing season median of 1.5 MPN/100mL at Station 5 to 12.1 MPN/100mL at Station 1 during 2013. The growing season median for all stations in 2013 was recorded at 5.2 MPN/100mL. There were no individual values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL during the growing season. From January to December, during the non-growing season months, there were 10 instances in the reservoir when *E. coli* densities were greater than the VADEQ maximum threshold (8.3% of total observations). In these occurrences, coliform densities ranged from 275.5 to 1119.9 *E. coli* MPN/100mL. Eight of these occurrences were noted at Station 5, in the mainbody of the reservoir, which is frequently populated by migratory and resident waterfowl. The isolated measurements of high *E. coli* densities could be related to these birds congregating on the open waters during cold weather months.

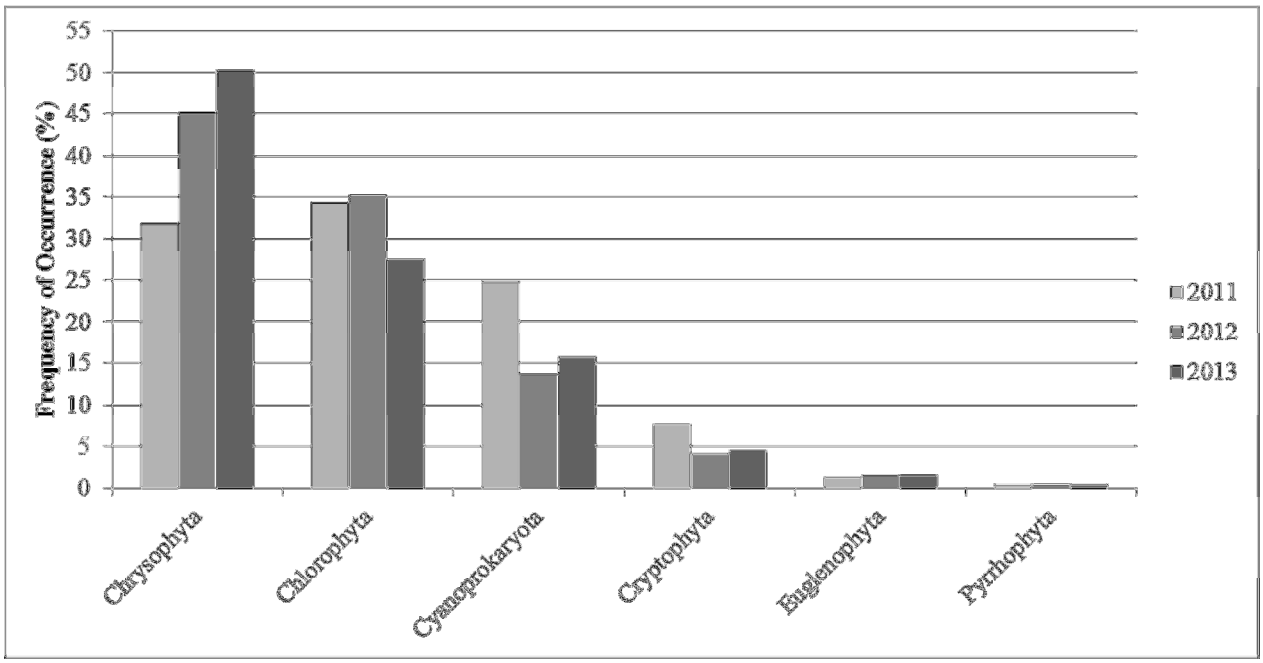
Temperature, pH, Conductivity, Lead and Zinc

Water temperature in Swift Creek Reservoir varied normally according to season during 2013. Surface temperatures throughout the reservoir ranged from 4.4 to 31.1^{o}C during the year with a median value of 19.1^{o}C. No individual surface temperatures exceeded the VADEQ maximum standard of 32.0^{o}C during 2013. Surface pH values ranged from 6.2 to 8.0 units with an annual in-lake median of 7.0 units, consistent with pH concentrations previously observed. None of the individual surface values fell outside of the 6.0 to 9.0 unit VADEQ acceptable range for pH. Conductivity measurements within the reservoir ranged from 20 to 250 µS/cm with an annual median of 74 µS/cm; an observation consistent with previously recorded values. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0210 mg/L with twenty measurable concentrations noted during 2013. At Station 1, in the upper backwater of the reservoir, measurable quantities of lead were recorded for each of the samplings. While the frequency of measurable quantities of lead increased from 2012 to 2013, the quantities were small, variable and transient throughout the reservoir and did not indicate a persistent concern. Zinc concentrations were typically below the laboratory's detection limit (0.05 mg/L) with only one measurable concentration noted during 2013. This measurement (0.071 mg/L) was recorded at Station 8 during the May 15, 2013 survey. This zinc level was transient and the subsequent sampling indicated no detectable level.

Algal Community Structure of Swift Creek Reservoir

A total of 46 individual genera of algae representing six phyla were documented in Swift Creek Reservoir during 2013. While nine taxa fewer than observed in 2012, an overall greater median algal density per month was observed in 2013 (6860 cells/mL) as compared with 2012 (6188 cells/mL). Analysis of the general types of algae by phyla in Swift Creek Reservoir (Figure 4) indicated that the community structure continued to be comprised largely of golden algae/diatoms (Chrysophyta, 50.4%) and green algae (Chlorophyta, 27.6%) combined (78%), similar to the composition noted in previous years. While common, the frequency of occurrence for the taste and odor producing blue-green algae (Cyanoprokaryota, 15.8%) has remained low as compared to 2011 (24.8%) and was similar to levels observed in 2012 (13.7%).

Figure 4. A comparison of the frequency of occurrence of six algae phyla observed in Swift Creek Reservoir 2011 - 2013.



The ten most common algal genera were identified (Table 7). These ten genera combined represented approximately 80% of all algae observed in 2013. While some of these genera are known to potentially affect the taste and odor of the production water, there were no widespread taste and odor related problems resulting from algae 2013.

Table 7. Ten most common taxa of algae observed in Swift Creek Reservoir 2013.

Number	Phyla	Genus	% of Total Observed	Taste/Odor Produced
1	Chrysophyta	*Chrysochromulina*	24.6	Not Known
2	Cyanoprokaryota	*Anabaena*	12.6	Rotten/Septic
3	Chlorophyta	*Ankistrodesmus*	9.8	Grassy/Musty
4	Chrysophyta	*Nitzschia*	8.2	Not Known
5	Chrysophyta	*Melosira*	7.6	Musty
6	Chlorophyta	*Crucigenia*	5.5	Not Known
7	Chlorophyta	*Dictyosphaerium*	3.2	Fishy
8	Chrysophyta	*Tabellaria*	2.9	Grassy/Fishy
9	Chlorophyta	*Scenedesmus*	2.6	Grassy
10	Chrysophyta	*Rhizosolenia*	2.6	Not Known

Status of *Hydrilla* and its Control in the Swift Creek Reservoir

As discussed in the previous Swift Creek Reservoir Water Quality Data Reports, the rapid growing invasive aquatic weed, *Hydrilla verticillata*, was first identified in the Swift Creek Reservoir in August 2009. After studying the problem, to include consultation with Dr. Kenneth Wagner (a recognized expert in aquatic weed control), action for the long-term management of *Hydrilla* was initiated by the introduction of 10,500 triploid grass carp (*Ctenopharyngodon idella*) to the reservoir in April 2010. The sterile grass carp were approximately 12 inches in length and weighed 1.0 to 1.5 pounds. An electrofishing survey conducted in September 2011 observed that seventy percent of the fish recovered had grown to 27 - 28 inches in length and weighed 8 - 10 pounds, indicating a healthy and growing population.

The reduction in the density and distribution of *Hydrilla* within the Swift Creek Reservoir, following the introduction of the grass carp, was rapid and successful. A combination of grazing pressure by the grass carp and natural die-back from cold winter water temperatures resulted in a substantially noticeable reduction to 107 acres of *Hydrilla* growth by June of 2011. By the August 2011 survey, no visible areas of *Hydrilla* were present and this observation was confirmed again in the October survey. Surveys conducted during 2012 and again in 2013 have confirmed that the grass carp continue to be effective in controlling the growth of *Hydrilla*. While the more vegetative structures of the plant have been virtually eliminated, it is anticipated that the plant's presence has not been completely removed. In addition to seed deposition, reproductive strategies such as root structures that produce tubers, fragments of leafy growth and turions on stems structures are all mechanisms that *Hydrilla* uses to survive. Constant and consistent evaluation of the situation is continuing and the eventual replacement of the existing, aging grass carp population is anticipated.

Conclusions

Indicators of water quality continue to suggest acceptable conditions in the Swift Creek Reservoir. An overall higher concentration of chlorophyll *a* was observed in 2013, as compared to previous years indicating an increased presence of algae in the reservoir. Throughout the reservoir, a general slight increase in total phosphorus concentration was observed. The growing season median total phosphorus concentration for the surface waters of the main body stations (Stations 4, 5, 6 and 8) was 0.036 mg/L as P; below the VADEQ nutrient threshold of 0.04 mg/L as P. The annual median phosphorus concentration for the surface water at all eight sites in Swift Creek Reservoir was 0.036 mg/L as P, below the county goal of 0.05 mg/L as P.

As in prior years, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper sections beginning in early April and lasting through mid-September. During this stratification period, dissolved oxygen concentrations within the epilimnion remained above the VADEQ standard of 4.0 mg/L for all stations.

Secchi disk readings ranged from 1.5 to 3.5 feet and are similar to those noted in prior reports. Individual site growing season medians for turbidity ranged from 2.4 to 17.0 NTUs with the greatest measurements observed in the shallow backwater stations. The growing season total nitrogen concentrations continued to be less than observed in past years with site medians ranging from 0.57 to 0.67 mg/L as N and indicated a decrease in nitrogen enrichment. There were no observations of individual *E. coli* density values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL during the growing season. Water temperature in Swift Creek Reservoir varied normally throughout the year. All surface pH values were within the VADEQ standard range of 6.0 – 9.0 units. Conductivity values within the reservoir were acceptable with an annual median of 74 µS/cm. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0210 mg/L with twenty measurable concentrations recorded during 2013. Zinc concentrations were typically below the laboratory's detection limit (0.05 mg/L) and were acceptable.

A total of 46 individual genera of algae representing six distinct phyla were documented in Swift Creek Reservoir during 2013 and analysis of the general types of algae indicated that the community structure continued to be dominated by golden algae/diatoms and green algae. There were no indications of algae related taste and odor problems reported in 2013. Vegetation surveys confirmed that the efforts in the reduction of the density of *Hydrilla* within the Swift Creek Reservoir have been rapid and successful. While the vegetative structures of the plant have been virtually eliminated, it is anticipated that the plant's presence has not been completely removed and constant and consistent evaluation is continuing with the eventual replacement of the existing, aging grass carp population anticipated. Efforts in 2014 will continue to emphasize the monitoring of source water quality, the extent and distribution of *Hydrilla*, and the health and growth of the grass carp.